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**U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center**

NOAA Technical Memorandum NMFS

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ABSTRACT

The endangered Hawaiian monk seal, *Monachus schauinslandi*, was studied on Laysan Island in the Northwestern Hawaiian Islands during 8 April-20 July 1987 and 30 March-16 July 1989. Data were collected on haul-out, behavior, and reproductive patterns; population structure; and factors affecting survival (primarily male aggression toward adult female and immature seals). In 1987, mean (\pm SD, $n = 26$) beach counts were 147.1 seals (± 19.6) including pups and 130.1 (± 17.7) excluding pups, and in 1989 ($n = 26$) were 100.2 (± 12.4) including pups and 82.8 (± 12.5) excluding pups. Five adult males were removed from the Laysan Island population and brought into captivity in May 1987. The total 1989 spring-summer population was 283 seals, and the sex ratio of adult males to adult females was 1.64:1. Thirty-four and 32 pups were born in 1987 and 1989, respectively. Fifty-two percent of the adult-sized females gave birth in 1989. The mean nursing periods were 42.1 days (± 5.7 , $n = 6$) and 37.6 (± 6.6 , $n = 18$) for pups monitored in 1987 and 1989, respectively. The mean axillary girth and straight dorsal length measurements for 23 weaned pups in each year were 112.3 cm (± 8.2) and 136.3 cm (± 7.9) in 1987 and 102.0 cm (± 10.6) and 127.7 cm (± 7.4) in 1989, respectively. Interatoll movement was documented for ten seals in 1987 and six in 1989. These animals moved between Laysan Island and either Lisianski Island, French Frigate Shoals, or Pearl and Hermes Reef. Sixteen potentially life-threatening conditions were observed in 1987, resulting in the death of 7 animals, while 47 incidents were documented in 1989, resulting in the death or probable deaths of 14 animals. Injuries caused from mounting by males accounted for 57% (4 of 7) of the deaths in 1987 and 71% (10 of 14) of the deaths and probable deaths of seals in 1989. Five seals in 1987 and 4 seals in 1989 were seen entangled, and 353 and 648 pieces of debris capable of entangling seals were inventoried and destroyed in 1987 and 1989, respectively.

CONTENTS

	Page
INTRODUCTION	1
MATERIALS AND METHODS	1
Individual Identification	2
Tagging and Measurements	2
Censuses and Patrols	2
Collection of Samples	4
RESULTS AND DISCUSSION	5
Population Abundance and Composition	5
Reproduction	6
Interatoll Movement	6
Factors Affecting Survival	6
Collection of Samples	6
ACKNOWLEDGMENTS	6
CITATIONS	8
TABLES	11

INTRODUCTION

Laysan Island (lat. 25°42'N, long. 171°44'W) is located in the Northwestern Hawaiian Islands approximately 709 miles northwest of Honolulu, and is within the Hawaiian Islands National Wildlife Refuge. This island is one of the major breeding and haul-out areas for the endangered Hawaiian monk seal, *Monachus schauinslandi*. Intensive research to monitor and enhance the recovery of the Laysan monk seal population has been conducted annually since 1977 in 3- to 9-month field camps; results have been presented in Johnson and Johnson (1978, 1981a, 1981b, 1984) for 1977-80, Knudtson (1981 and 1983) for 1981, Alcorn (1984) for 1982, Alcorn and Buelna (1989) for 1983, Johanos et al. (1987) for 1984, Johanos and Austin (1988) and Becker et al. (1989) for 1985, Alcorn and Westlake (1993) for 1986, Johanos et al. (1990) for 1988, and Lombard et al. (1994) for 1990. Additional historical monk seal counts are listed in Hiruki and Ragen (1992). The data collected on the Hawaiian monk seal on Laysan Island in 1987 and 1989 are summarized in this report.

In 1987, the primary objectives of field studies were to reduce the sex ratio imbalance by taking five adult males into permanent captivity, tag adult and subadult males for permanent identification, and monitor male aggression toward female and immature seals. In 1989, the primary objectives were to identify the entire monk seal population and monitor breeding activity by collecting data on haul-out and behavior patterns, particularly male aggression toward adult female and immature seals. Other objectives during both seasons included conducting beach counts; identifying animals in the population and maintaining identification of individual seals by recording natural markings; applying and maintaining bleach marks on males considered for capture in 1987 and all adults and subadults in 1989; tagging and measuring weaned pups and retagging animals with lost or damaged tags; monitoring survival, reproduction, interatoll movement, injuries, and entanglements; performing necropsies; inventorying and destroying debris capable of entangling seals and turtles; and collecting tissue samples for DNA analysis of paternity patterns, and spew samples (during both years) and scat samples (in 1989) for food habit analysis.

MATERIALS AND METHODS

Data were collected by NMFS personnel during 8 April-20 July in 1987 and 30 March-16 July in 1989. Additional information (e.g., birth of one pup, and the weaning dates and tagging of three pups) was documented by U.S. Fish and Wildlife Service (USFWS) personnel on Laysan Island during 17 July-3 September in 1989.

Individual Identification

Natural markings, scars, applied bleach marks, and tags were used to identify individual seals. Seals were also classified by size and sex. Procedures for seal identification and size classification are detailed in Stone (1984). During both seasons, seal scar card drawings and photographs were added to the individual identification files initiated in 1982. Thirteen adult males were bleach-marked in 1987, and 183 non-pups and 25 weaned pups were bleach-marked in 1989; methods are described in Stone (1984) and Johanos et al. (1987). Some of the bleach marks seen in 1989 were applied to the animals post-molt in 1988. When possible in 1989, molting seals were re-marked to maintain their identities for the next season.

The population total included all unique individuals seen alive on Laysan Island during March to August and all pups born during the year. If a seal was seen at more than one island during this period, it was included in the population where it was first seen unless it pupped. A parturient female was always included in the population where she pupped if she was seen there anytime from March to August.

Tagging and Measurements

Tan "cohort" Temple tags (Lombard et al., 1994) were applied to weaned pups on Laysan Island in both 1987 and 1989. A single Temple tag was placed at the trailing edge of each hind flipper in the webbing, usually between the fourth and fifth digits (Gilmartin et al., 1986). All pups were tagged as soon as possible after weaning. At the same time, the axillary girth (American Society of Mammalogists, 1967) and straight dorsal length (Winchell, 1990) were measured for each tagged pup. Since pups lose weight after weaning, only those measurements taken within 2 weeks after weaning were used to determine mean weaning girth for the season.

Six seals were retagged with Temple tags in 1987 and 11 were retagged in 1989. In 1987, metal (Monel) tags were applied to the trailing edge of the webbing between the digits on one or both hind flippers of adult and subadult males (Alcorn and Buelna, 1989).

Censuses and Patrols

The primary methods of data collection were censuses and patrols, which were scheduled to ensure that the entire 11-km island perimeter (divided into 20 approximately equal-sized sectors; Alcorn, 1984) was monitored about five times each week from 8 April to 15 July 1987 and once each day during 4 April to 7 July 1989. In previous years, male aggression had been observed in sectors 1-8 and 18-20 (Johnson and Johnson, 1981b;

Alcorn, 1984; Johanos et al., 1987; Johanos and Austin, 1988; Alcorn and Buelna, 1989; Johanos et al., 1990; and Alcorn and Westlake, 1993) and, in 1989, these areas were monitored twice daily on 34% (32/93) of the data collection days. Census and patrol data were recorded on the standard census form (Alcorn and Buelna, 1989 for 1987 version; Forsyth et al., 1988 for 1989 version), following the coding instructions (Reddy, 1989 for 1987 version; Craig et al., 1992 for 1989 version).

Censuses consisted of timed, standardized beach counts of seals during which the entire island was surveyed (Johanos et al., 1987). As seals spend approximately one-third of their lives on land, the census counts only provide an index of the total population. Census counts began at 1300 and were conducted every third or fourth day in 1987 and every fourth day in 1989. To avoid disturbing seals and affecting census counts, handling of animals and bleaching activities were typically conducted after the completion of the census.

Patrols consisted of untimed surveys of all or a portion of the island perimeter. Information collected during patrols was similar to that collected during censuses. In 1987, the primary purpose of the patrols was to tag adult and subadult males. In 1989, standardized patrols focused on activity patterns of adults and large subadults to document male aggression and detect mobbing incidents in which multiple males attempted to mate with a single seal, usually an adult female, causing injury or death of that seal (e.g., Alcorn, 1984). During these patrols, attention was directed out to sea as much as possible, as mobbings have been documented most frequently in the water.

During all observation periods (i.e., censuses, patrols, and incidental sightings), observers attempted to minimize seal disturbance by walking above the beach crest and using vegetation for cover. Additionally, special efforts were directed toward observation and documentation of (1) births, pup exchanges, weanings, (2) injuries, (3) entanglements in marine debris, (4) mating activities and male aggression, and (5) deaths.

Nursing (or lactation) periods were defined as the length of time (days) from the birth (or pupping) until the end of the last nursing relationship for the pup (or parturient female). Temporary breaks in the nursing relationship were not subtracted from the total. Nursing periods which were terminated by the death of a pup were excluded from this analysis. When the exact date was not known for either a birth or weaning event but the event was known to have occurred within an interval of four days or less, the event date was estimated as the mid-point of the interval. If the interval was greater than 4 days, then the data were not used in this analysis.

Injury types and their probable causes were classified according to descriptions in Hiruki et al. (1993). Injuries

considered potentially life threatening had at least one of the following conditions: (1) three abscesses < 5 cm in diameter or one abscess \geq 5 cm in diameter; (2) an amputation of greater than one digit of a flipper (either foreflipper or hind flipper); (3) densely spaced (overlapping) scratches, abrasions, or lacerations (through the skin layer) covering an area equivalent to 50 percent of the dorsum, or evidence of extensive underlying tissue damage (including uneven or darkened surface of the injured area, leaching fluids, or impaired seal movement); or (4) three punctures or gaping wounds (missing skin or extending into the fat) < 5 cm in diameter (or largest dimension), or one gaping wound \geq 5 cm in diameter (or largest dimension).

Male aggression was defined as incidents where adult or subadult males repeatedly bite the dorsum of a subject seal, attempt to mount the subject, and try to prevent its escape. These incidents must either simultaneously involve more than one male aggressor or result in injury to the subject of at least one puncture or gaping wound (missing skin or extending into the fat) or 15 scratches on the dorsum or laterals. Post-mobbing aggregations were defined as groups of males on the beach attending a seal with a new mounting injury of severity described above.

Nursing pups were considered to have died if they disappeared within 3 weeks of birth. A seal was considered to have died if it disappeared following an injury with a severity considered potentially life threatening (described earlier) or had been severely emaciated (with extreme loss of weight so that its skeleton was clearly evident), and one of the following conditions was observed: (1) the seal was lethargic, had trouble moving, or floated listlessly in the water, and disappeared more than 1 week before the end of data collection; or (2) the seal was in deteriorating condition (loss of weight, enlargement of abscesses, sloughing of skin), and was not seen for at least 10 counts or patrols, or 1 month, whichever was longer.

Collection of Samples

Tissue samples (skin tissue plugs) for DNA analysis (paternity analyses) were collected from animals during Temple tag application in both 1987 and 1989. In 1989, heart, muscle, and skin tissues from freshly dead animals and fur samples from molting seals also were collected for DNA analysis. Fresh tissue samples were immediately frozen. The results of these analyses will be reported elsewhere.

External examinations, including observations, photographs, and measurements, were made of each dead seal recovered to assess cause of death and age/size-specific mortality rates. If the death was recent, a necropsy was performed (Winchell, 1990), which included an internal examination and collection of samples of tissues, parasites, and stomach contents. Skulls from all

animals except nursing pups were collected, flensed, and dried for evaluation of skull characteristics and of aging.

Throughout the field season, all nets, lines, and other debris items capable of entangling seals and turtles were collected, inventoried, and destroyed following the methods in Johanos and Kam (1986). To determine monk seal food habits, spewings were collected in 1987 and 1989 and scats were collected in 1989 from animals of known size and sex, following the methods in Alcorn (1984). Prey items from spewings were frozen for ciguatera analysis. Results of food habits and ciguatera analysis will be reported elsewhere.

RESULTS AND DISCUSSION

Population Abundance and Composition

In 1987, the mean census counts (\pm SD; $n = 26$) were 147.1 seals (± 19.6) including pups and 130.1 seals (± 17.7) excluding pups (Table 1). In 1989, the mean census counts (\pm SD; $n = 26$) were 100.2 (± 12.4) including pups and 82.8 (± 12.5) excluding pups (Table 1). Counts are reported both with and without pups; with pups for consistency with historical information; and without pups as these counts are a less variable index of the total population.

On 1 May 1987, five adult males were captured and removed from the Laysan population and were brought into captivity. Additionally, 52 adult and 3 subadult males were successfully tagged and resighted in 1987. In 1987, only the juvenile and pup portion of the population (79 seals) was identified (Table 2A).

The total 1989 population was 283 individuals (251 excluding pups; Table 2B). The sex ratios for non-pup immatures and for adults were 0.89:1 (41 males: 46 females) and 1.64:1 (102 males: 62 females), respectively (Table 2B). Within the adult class, the skewed sex ratio was due to older seals, where the male to female ratio was 1.78:1 (89 males: 50 females). For the seals of adult-size but \leq age 6, the sex ratio was 1.08:1 (13 males: 12 females). In Table 3 the number of pups tagged on Laysan Island during 1983-88 and resighted on Laysan Island in 1987 and 1989 is reported.

Reproduction

In 1987, 34 pups were born; 3 pups died prior to weaning, and 3 were still nursing at the end of the survey period (Table 4A). In 1989, 32 pups were born, 1 of which died prior to weaning (Table 4B). The mean (\pm SD) nursing period in 1987 for pups was 42.1 days (± 5.7 , $n = 6$; Table 4C) and the lactation period for adult females was 43.5 days (± 4.5 , $n = 14$). In 1989, the mean nursing period for pups was 37.6 (± 6.6 , $n = 18$; Table

4D). In each year, 23 pups were measured within 2 weeks after weaning (Tables 4C and 4D), 1 birth was observed, and 1 pup exchange was documented. The total number of females was not determined in 1987, and birth rate could not be estimated. In 1989, the birth rate for adult-sized females was 0.52 (32 births per 62 females).

Interatoll Movement

In 1987, known interatoll movement was documented for ten individuals which moved between Laysan Island and either Lisianski Island, French Frigate Shoals, or Pearl and Hermes Reef (Table 5). In 1989, six animals moved between Laysan Island and either Lisianski Island or French Frigate Shoals (Table 5).

Factors Affecting Survival

During the 1987 field season, 16 potentially life-threatening conditions were documented that resulted in the death of 7 animals (Table 6A). For the 1989 field season, 47 potentially life-threatening conditions were documented that resulted in the death of 12 animals and probable deaths of 2 seals (Table 6B). Although many animals had recent dorsal injuries indicating mounting by males (Table 6), none of the incidents were observed. These events accounted for 57% (4 of 7) of the deaths in 1987 and 71% (10 of 14) of the deaths and probable deaths in 1989. In addition to the deaths in the tables, one fetus (~10 cm long) was found dead on the beach; the mother was not identified. In 1989, one pup nursed only 19 days, approximately half of a normal nursing period and, although she survived until the end of the field camp (1 month after weaning), she was not seen in 1990.

Collection of Samples

Tissue samples for DNA analysis were collected from 7 tagged seals in 1987 and 40 tagged seals, 10 freshly dead animals, and 45 molting animals in 1989. Necropsies were performed and tissue samples were collected from four seals in 1987 and eight seals in 1989. In 1987, 353 pieces of potentially dangerous debris were inventoried and destroyed; and in 1989, 648 pieces were inventoried and destroyed. For diet analysis, one spew was collected in 1987, and three spews and two scats were collected in 1989.

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TABLES

Table 1.--Summary statistics for Hawaiian monk seal census counts on Laysan Island from 11 April to 13 July 1987 ($n = 26$) and from 1 April to 10 July 1989 ($n = 26$).

Size	Number of individuals			
	1987		1989	
	Mean	Standard deviation	Mean	Standard deviation
Adults	59.8	10.5	49.0	8.0
Male	30.0	6.4	25.4	7.8
Female	17.2	3.4	19.1	4.3
Unknown	12.7	6.0	4.5	3.5
Subadults	40.8	11.8	3.0	7.3
Male	10.9	3.0	9.9	3.5
Female	16.5	5.5	10.8	3.7
Unknown	13.4	6.6	2.2	2.6
Juveniles	29.4	5.1	10.8	2.5
Male	12.2	3.7	5.3	1.4
Female	13.5	2.9	4.8	2.0
Unknown	3.7	3.1	0.7	1.3
Pups	17.0	4.2	17.5	3.2
Male	7.6	2.9	6.0	3.1
Female	7.7	3.1	5.2	3.3
Unknown	1.7	2.3	6.3	4.6
Non-pup total	130.1	17.7	82.8	12.5
Grand total	147.1	19.6	100.2	12.4

Table 2A.--Composition of the Laysan Island Hawaiian monk seal population during the spring and summer of 1987.
Total includes all pups born during the calendar year.

Size	Number of seals				Sex ratio
	Male	Female	Unknown	Total	Male:Female
Juveniles	23	22	0	45	1.04:1
Pups	14	17 ^a	3 ^b	34	0.82:1

^aIncludes one neonatal pup death.

^bIncludes two neonatal pup deaths.

Table 2B.--Composition of the Laysan Island Hawaiian monk seal population during the spring and summer of 1989.
Total includes all pups born during the calendar year.

Size	Number of seals			Sex ratio
	Male	Female	Total	Male:Female
Adults	102	62	164	1.64:1
Subadults	29	32	61	0.91:1
Juveniles	12	14	26	0.86:1
Pups	17	15	32	1.13:1
Non-pup total	143	108	251	1.32:1
Grand total	160	123	283	1.30:1

Table 3.--Summary of tagged known-age seals born on Laysan Island and resighted there in 1987 and 1989.

Year born	Sex	No. originally tagged	Number resighted	
			1987	1989
1983	Male	10	3	3
	Female	10	8	9
1984	Male	16	11	9
	Female	13	10	7
1985	Male	16	11	6
	Female	14	9	7
1986	Male	15	13	10
	Female	17	12	9
1987	Male	13	--	6
	Female	15	--	11
1988	Male	23	--	13
	Female	17	--	11

Table 4A.--Summary of Hawaiian monk seals born on Laysan Island in 1987.

Event	Number of pups			
	Male	Female	Unknown	Total
Born	14	17	3	34
Died/probably died prior to weaning	0	1	2	3
Weaned	13 ^a	15 ^a	0 ^a	28 ^a
Tagged	13	15	0	28

^aThree pups (one male, one female, and one of unknown sex) were still nursing at the end of the field camp.

Table 4B.--Summary of Hawaiian monk seals born on Laysan Island in 1989.

Event	Number of pups			
	Male	Female	Unknown	Total
Born	17	15	0	32
Died/probably died prior to weaning	0	1	0	1
Weaned	17	14	0	31
Tagged	16 ^a	13 ^b	0	29

^aOne pup weaned before research began, and disappeared before it could be tagged.

^bOne pup nursed only 20 days and was measured but not tagged.

Table 4C.--Summary of nursing period and measurements of weaned pups on Laysan Island in 1987. Nursing periods were calculated where both birth and weaning events were known to have occurred within an interval of ≤ 4 days. All measurements were taken within 2 weeks after weaning, and no weaned pups had an axillary girth ≤ 95 cm.

	Nursing period (days)	Axillary girth (cm)	Straight dorsal length (cm)
Mean	42.1	112.3	136.3
St. Dev.	5.7	8.2	7.9
<i>n</i>	6.0	23.0	23.0

Table 4D.--Summary of nursing period and measurements of weaned pups on Laysan Island in 1989. Nursing periods were calculated where both birth and weaning events were known to have occurred within an interval of ≤ 4 days. All measurements were taken within 2 weeks after weaning and include 5 weaned pups with axillary girths ≤ 95 cm.

	Nursing period (days)	Axillary girth (cm)	Straight dorsal length (cm)
Mean	37.6	102.0	127.7
St. Dev.	6.6	10.6	7.4
<i>n</i>	18.0	23.0	23.0

Table 5A.--Known movement of Hawaiian monk seals to Laysan Island from other locations in 1987 and 1989.

Original location	Number, size and sex class	
	1987	1989
Lisianski Island	1 subadult female, 4 subadult males, 1 juvenile female	1 adult male
French Frigate Shoals	1 juvenile female 1 adult female	2 adult females, 2 adult males
Pearl and Hermes Reef	1 subadult female	-

Table 5B.--Known movement of Hawaiian monk seals from Laysan Island to other locations in 1987 and 1989.

Destination	Number, size and sex class	
	1987	1989
Lisianski Island	1 adult male, 2 subadult female, 1 subadult male,	-
Pearl and Hermes Reef	1 subadult male	-
French Frigate Shoals	1 adult female	2 adult females, 1 adult male, 1 juvenile male

Table 6A.--Factors affecting survival of Hawaiian monk seals on Laysan Island in 1987.

Size	Sex	No. of incidents	Outcome	
			Injured	Died
Attack by large shark				
Subadult	Male	1	1	0
Mounting by males				
Adult	Female	3	1	2
Subadult	Male	1	0	1
Weaned pup	Female	1	0	1
Entanglement				
Adult	Female	2 ^a	0	0
Subadult	Female	1 ^a	0	0
Juvenile	Male	1 ^b	0	0
	Unknown	1 ^b	0	0
Other/Unknown				
Adult	Female	1	1	0
Juvenile	Male	1	1	0
Nursing pup	Female	1	0	1
	Unknown	2	0	2

^aSeals escaped from entangling object by themselves.

^bSeals were released from entangling object by researchers without restraint.

Table 6B.--Factors affecting survival of Hawaiian monk seals on Laysan Island in 1989.

Size	Sex	No. of incidents	Outcome		
			Injured	Died	Probably died
Attack by large shark					
Adult	Male	8	8	0	0
	Female	3	3	0	0
Subadult	Male	1	1	0	0
	Female	1	1	0	0
Mounting by males					
Adult	Female	15	7	7 ^a	1
	Unknown	1	1	0	0
Subadult	Male	3	2	1	0
	Female	1	1	0	0
Weaned pup	Male	1	0	0	1
Entanglement					
Adult	Female	3 ^b	0	0	0
Subadult	Male	1 ^c	0	0	0
Other/Unknown					
Adult	Male	5	2	3	0
	Unknown	1	1	0	0
Subadult	Male	1	1	0	0
Immature	Unknown	1	0	1 ^d	0
Weaned pup	Male	1	1	0	0

^aOne seal that had been injured by males was attacked by a shark.

^bTwo females escaped on their own, and the third one was restrained while researchers removed the entangling object.

^cSeal escaped from entangling object by itself.

^dSkull and attached foreflipper were found in the stomach of a dead tiger shark that washed ashore. It is unknown if the seal were alive prior to the shark attack.

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